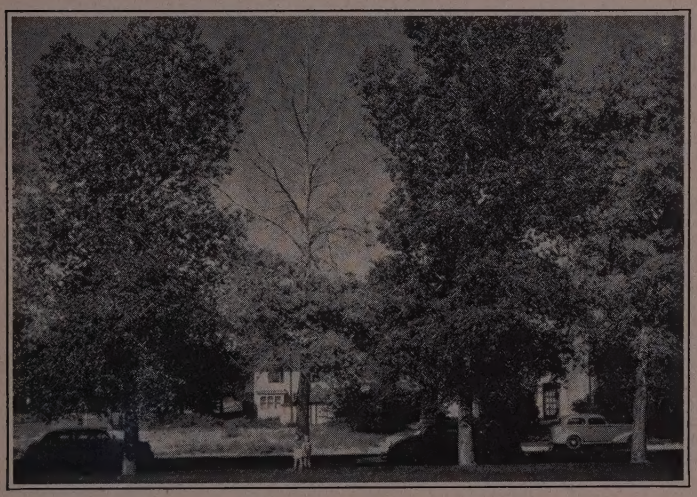
BULLETIN NO. 252 **MAY, 1942**

UNIVERSITY OF WYOMING AGRICULTURAL EXPERIMENT STATION



Alternate trees showing a chlorotic condition, the center one of which is almost dead. The two trees on either side of the partially dead tree had been treated with ferric phosphate the previous season.

The Control of Chlorosis in Cottonwood Trees and Other Plants

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THE CONTROL OF CHLOROSIS IN COTTONWOOD TREES AND OTHER PLANTS

By G. H. Starr

IMPORTANCE

Chlorosis, or yellowing of plants, is a very common malady in Wyoming as well as in other Rocky Mountain States. Many species of trees, such as cottonwood, box elder, willow, maple, hawthorn, Russian olive, and apple, are often seriously afflicted. Usually the older trees are more susceptible to this trouble, but often younger trees are likewise affected. Shrubs and perennials such as spirea, caragana, roses, peonies, and strawberries, are also susceptible to chlorosis in Wyoming. This work on the control of chlorosis was undertaken because of the prevalence of chlorosis in cottonwood trees on the University campus, in other parts of Laramie, and in other parts of Wyoming as well.

NATURE AND CAUSE

Leaves become yellow because they cannot produce the normal amount of chlorophyll, the green coloring matter of the leaf. The yellow color appears gradually and may be seen first between the veins of the leaves. This portion will continue to turn yellow while the veins remain green. The larger veins are the last to become yellow. At this stage the tips and edges of the leaves begin to turn brown and this condition may continue until the leaves are entirely brown. Trees in late stages of chlorosis have very little reserve food and vigor and will soon die. The death of such trees is conspicuous in the spring, when they fail to leaf out.

The yellowing may appear uniformly in all leaves, or it may be localized in one or more of the branches. In the latter case, leaves on the lower branches are usually the first to show symptoms of chlorosis.

A number of factors may cause chlorosis, but the chief ones are those associated with the nutrition of the plant. Certain minerals such as magnesium and iron must be present for normal

Figure 1. Showing the location of the holes in treating a tree and the proper position of the bit in boring them. Also the improvised funnel-like device used to introduce the ferric phosphate into the tree. The funnel tip is slightly smaller than the hole, so that it may be partially inserted to prevent the spilling of the iron salt. The rod also is slightly smaller than the hole in the funnel tip and enables one to push the ferric phosphate into the hole in the tree. The box in the background contains small envelopes with various labeled amounts of ferric phosphate. Where several trees are to be treated this method facilitates the treating process.

chlorophyll manufacture. The former is used directly and the latter indirectly in its production. These minerals come from the soil, and their solubility may be affected greatly by an acid or an alkaline soil reaction and by the degree of the reaction. Many of the soils in this area are high in lime, with a resultant alkaline reaction. It is possible for minerals to be present in the soil and yet not be available to the plant. The lack of available iron is probably the most important and common cause of chlorosis. This is not only true in Wyoming but also in other parts of this country and of the world where chlorosis is found. In addition, the yellowing of plants may sometimes be caused by the following factors or by a combination of them: The lack of nitrogen, magnesium or other minerals; excess of water; low temperatures and lack of light. However, these are of minor importance in comparison with the lack of available iron.

In addition, certain diseases may be responsible for the yellow condition of plants. Virus diseases may cause plants to become yellow because of the infection within the plant. This is true especially of the various mosaic diseases and yellows. Plants affected with root rot may also turn yellow if the roots are badly infected. Mildews and rusts may cause yellowing of plants, but their presence can be detected easily by the grayish color and the brownish dusty spots caused respectively by the above diseases. Plants affected with any of the above troubles will not be benefited by treatments designed to cure chlorosis caused by the lack of iron.

REVIEW OF LITERATURE

Many workers have reported their results on various phases of chlorosis work but only those will be mentioned here which deal with some phase of its control.

The spray method, in which a solution of ferrous sulphate (copperas) is sprayed on the leaves of plants, is used widely as a temporary method in treating chlorosis. Wann in Utah reports the successful use of this spray at the rate of ½ pound per gallon for chlorotic plants in general (9) and in a later publication (10) recommends its use on grapes, in particular, at the rate of 10 pounds per 100 gallons of water. Bennett (3), working in California, suggested the use of this spray at the rate of 1 ounce per gallon of water where only a few trees are to be sprayed. However, he stated that it has not proved successful in commercial use with fruit trees.

Reports from New Mexico (5) indicated also that this method was not satisfactory on a commercial scale. However, a 1 per cent solution of iron sulphate gave very good results when used on chlorotic jack pine and western yellow pine seedlings at the Morton Nursery in Nebraska (7); Jensen (6), working in Puerto Rico with chlorotic citrus trees, found that a zinc sulphate solution sprayed on the leaves was beneficial, while copper sulphate, iron sulphate, and manganese sulphate gave no response. Workers in Arizona (4) reported that both ferrous sulphate and manganese sulphate were without permanent effect when sprayed on chlorotic citrus trees.

Montana workers (1) have reported satisfactory results through the use of nails driven into chlorotic apple trees. This method has also been used to some extent in New Mexico (5) as well, as that of burying scrap iron around the base of trees. Both methods are said to be slow and other treatments preferable.

The method of treating the soil with iron compounds and other materials has been investigated in many places. The results in New Mexico perhaps have been the most successful. Crawford (5) reports that the use of barnyard manure and other acid or acid-forming materials, such as sulperphosphate, sulphur, and sulphuric acid, used in combination with iron and aluminum sulphate proved to be very effective in the control of chlorosis of grapes, cottonwoods, nasturtiums, petunias, and other plants. Acid solutions of iron and aluminum sulphate also gave good results for chlorosis of grapes. Bennett (3) has described the trench method, in which copperas is used in treating fruit trees in California. He states that this method is expensive but that it has been used successfully, especially with ornamental plants. A modification of this method is described in which holes are bored in the soil around the tree and the salt applied in that manner.

Fertilizer tests in Arizona (4) in which both manure and double-superphosphate was applied deeply around the citrus trees, gave largely negative results. However, favorable results are reported through the use of heavy irrigations in basins followed by a drying out of the soil almost to the wilting point. Wann (9) in Utah suggests the use of manure, ammonium sulphate or sulphur in the soil but states that it is difficult to accomplish much by this method. In a later publication he also states (10) that little effect was observed from these treatments. Poesch (8) in Ohio found that ferrous sulphate, used in soil treatments, gave good results in the control of chlorosis of hydrangeas, while ferric phosphate was beneficial to a lesser degree. Zinc sulphate and manganous sulphate did not correct the chlorotic condition.

Numerous workers have tried the method of injecting iron compounds directly into the tree either in solution or as a dry salt. Bennett (3) reports the use of iron sulphate, iron chloride, iron nitrate, ferrous or ferric citrate or tartrate, or iron ammonium

citrate dissolved in water and used in the injection method for fruit trees. Ferrous or ferric citrate are recommended to be used in the dry injection method on pear trees. In New Mexico (5) both iron citrate and iron phosphate have given satisfactory results for tree chlorosis. A dosage of 1 gram of dry powder is used for each inch of tree diameter. Wann (9) also reported success through the use of these two iron compounds. Later (10) he found that in addition to these the following compounds gave beneficial results with grapes: iron ammonium citrate, iron ammonium phosphate, iron ammonium oxalate, iron nitrate and a mixture of iron phosphate and ammonium oxalate.

Wann also stated that efforts to obtain "strains" of Concord grapes by the selection of promising cuttings were not successful. However, Concord scious grafted on vinifera roots produced vigorous vines practically free from chlorosis. Colorado workers (2) have tested 40 varieties of grapes and found varying resistance to chlorosis. These were classed as resistant, medium resistant, and susceptible.

EXPERIMENTAL METHODS USED IN TREATING CHLOROSIS

During this investigation on chlorosis several methods of treatment were used on the University campus, some in a limited way. The injection method, however, was used extensively, especially with cottonwood trees and to a lesser extent with box elder, willow, hawthorn, Russian olive, and apple trees. Most of the treatment data on box elder trees was gathered from trees treated in a city park at Pine Bluffs, Wyoming, (Fig. 4), while that on apple trees was from a few trees treated at the State Horticultural Farm at Lander, Wyoming.

Use of iron nails. In 1936 iron nails were driven in 25 cottonwood trees showing a slight to considerable degree of chlorosis on the University campus. From 12 to 24 nails were driven in each tree which varied from 6 to 10 inches in diameter. Two years later 4 of the trees were slightly better, 5 were in the same condition and 16 were worse than they were when treated. One of the trees was so severely affected with chlorosis that it

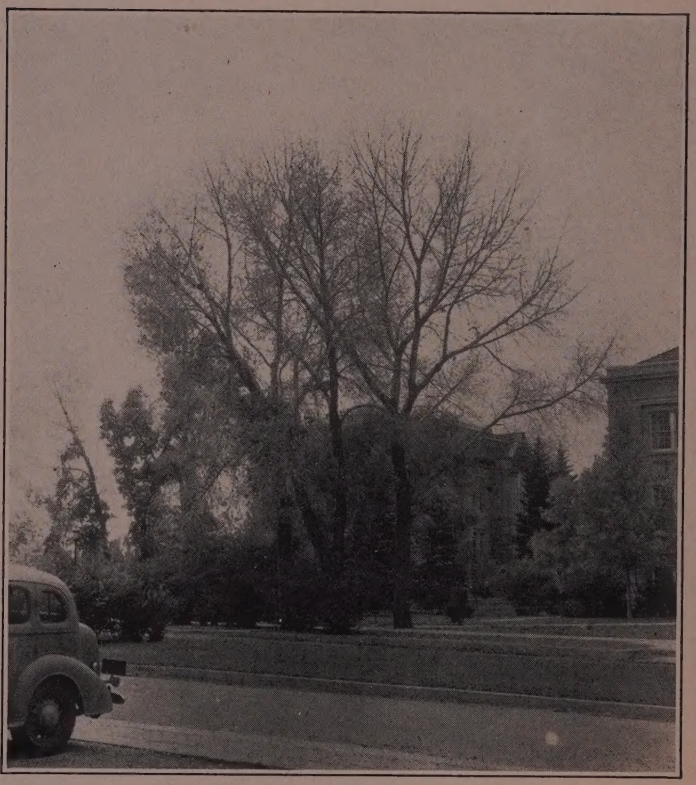

Figure 2. These three large trees show the result of a normal dosage of ferric phosphate when used in treating them the first part of July. Almost all of the leaves are off.
(See Figure 3)

was decided to discontinue this experiment and treat the other trees by the injection method to prevent them from dying. The action of iron nails, apparently is very slow under Laramie conditions as it did not maintain the condition of most of the trees tested. The results were such that this method is not recommended as a treatment for chlorosis of cottonwood trees, under conditions similar to those prevailing in Laramie.

Spraying with Iron Salts. During the past few years, numerous chlorotic plants have been sprayed on the campus with ferrous sulphate solution. This was used at the rate of 4 ounces of ferrous sulphate to a gallon of water. It may be used at twice this rate on some plants but may injure others which are more tender. The following plants have been successfully treated with this spray: cottonwoods, willows, hawthorn, spirea, roses, and strawberries. Blue grass lawns may also be restored to a dark green color by this treatment, if the trouble is an iron deficiency.

The spray method is commonly used as a *temporary* treatment for chlorotic shrubs, flowers and smaller plants which are too small to be treated by the injection method. Plants of this size can usually be brought back to a normal green condition in a short time. The spray treatment usually has to be repeated each season. Finely pulverized copperas is best adapted for this purpose as it goes into solution easier than the lump form. The spraying should be done in the evening or during cloudy weather, so that the rate of evaporation will be reduced to a minimum, giving a longer period for absorption of the iron. The leaves should be thoroughly covered with the spray. Blossoms should not be sprayed as they are likely to be injured by the iron compound. Plants with hairy leaves probably will be benefited more than ones with smooth, waxy leaves because of better adherence of the solution. It may be necessary to repeat this process once or twice at about ten-day intervals before the normal green color is restored.

Soil Treatments. During the past few years, numerous soil treatments have been tried for chlorosis of cottonwood trees and other plants growing on the campus of the University of Wyoming. A few treatments have given benefits in some cases, but to date none has been successful enough to warrant a general recommendation. Ferrous sulphate and aluminum sulphate have been used together in soil treatments and in some cases they have given marked improvements in the trees and shrubs, while in others the improvement has been negligible.

More recently sulphur alone, and in combination with ferrous sulphate, has been tried in treating the soil for the cure of

chlorotic shrubs and trees. Although no benefits were seen the first year of the treatment, it is possible that more time is required for results to be evident.

Other soil-treatment tests are now in progress, and it may be that some successful method will be found as a result of this work.

The Injection Method. Injection of iron salts was tried on the University campus as early as 1928. However, it was not so successful in the early years of the experimental work because the iron was placed in the trees inside of gelatin capsules. In these trials a comparatively small amount of iron salt was introduced, the holes were small, and a portion of the hole was taken up by the capsule. Moreover, the capsules caused the iron to be slowly available because the capsules had to be at least partly dissolved before the iron could enter the circulation of the tree.

In the spring of 1938, ferric phosphate was used in larger quantities than had been used previously, and without the capsule. It was introduced in bulk form into the holes bored in the trees. All the trees treated were cottonwoods. The results were so striking and successful that additional trees were treated as late as July 10. Treatment at this time caused nearly all the leaves to fall, although within a period of six weeks, new green leaves had replaced the older chlorotic ones. Since that time the ferric phosphate injection treatment has been the chief means of maintaining a green leaf condition of the University campus trees.

INJECTING TREES WITH IRON SALTS

How to Treat. Holes one-half inch in diameter or smaller are bored on a downward slant into the trunk or larger roots to a depth of from one to three inches, depending on the size of the tree. These holes should be spaced around the tree so that they are from four to six inches apart. This is best done by boring the first two holes on opposite sides of the tree and by spacing the others between these, until the required amount of iron salt is used up. In small trees it is advisable to use at least two holes rather than to put all the salt in one. This gives a better distribution of the iron to all branches of the tree. The holes may be bored slightly below the ground line by removing the soil to a depth of a few inches around the base of the tree, or they may be bored above ground. The former is preferable, in that the holes can be covered by replacing the dirt, thus avoiding the unsightly appearance of the wax-covered holes.

The holes are filled to within one-fourth inch of the top or exterior with the dry ferric phosphate powder by means of a funnel or a modified funnel as shown in Figure 1. A stick or rod should be used to push the material down and compress it in the hole. A sealing substance such as a grafting compound, tree surgery material or even putty may be used to seal the hole, pressing it down firmly over the iron salt. This is important, for if it is not done properly, sap may ooze from the hole later when the sap rises in the tree. These holes usually callus over in about one season's growth so that if they can be tightly plugged for the first season, they will be permanently sealed by new growth of woody tissue.

When to Treat. Trees should be treated during their dormant stage, that is, at any time after the leaves drop off in the fall until the buds start to swell in the spring.

If trees are very chlorotic when they leaf out in the spring, it may be questionable if they will live through the season, because they are unable to make sufficient food under such conditions to sustain life very long. In such cases it may be advisable to treat them even after the leaves come out. If this is done, it is recommended that the dosage be sub-divided and injected as follows:

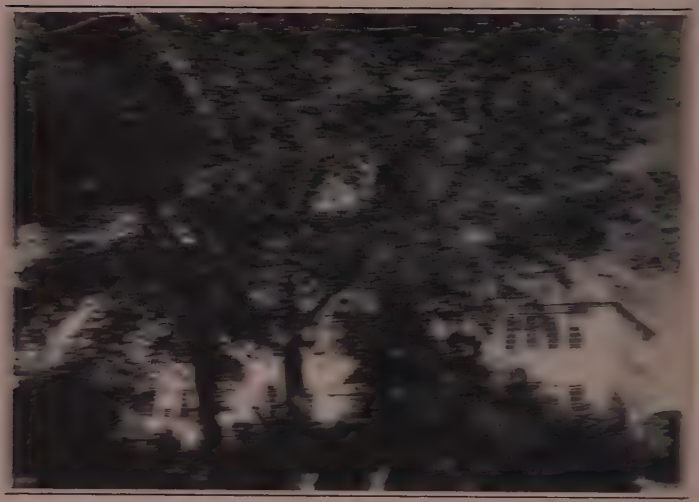

Figure 2. The same scene as that shown in Figure 1, but a different view [illegible]

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successful. On the other hand, the following ferric compounds have been successfully used in chlorosis work at this station: ferric phosphate, ferric citrate, ferric oxalate, and ferric nitrate. The last two compounds have been tried on only a few trees. Ferric sulphate, ferric chloride, ferric oxide, and ferric ammonium sulphate have also been tried but without success. Other non-ferric phosphate salts have also been tested (manganous phosphate and sodium phosphate) also without success on cottonwood trees. As ferric phosphate has given the best results and has been used most extensively, it is to be recommended. However, if the phosphate cannot be obtained, ferric citrate may be used instead.

Size of Dose and Source of Supply. A satisfactory dose in relation to the size of tree is found as follows: The diameter of the tree in inches (near base) multiplied by 5 will give the number of grams. If the dose is measured in ounces, divide the diameter in inches by 5 and the result will give the number of ounces. Larger dosages than this can be used; in fact, five times this rate has been used with no ill effects. Willows apparently require a larger dosage than cottonwoods, and it is suggested that for this kind of tree the dosage for cottonwoods be increased by one-third.

Very few local drug stores carry ferric phosphate in stock but it is carried regularly by wholesale druggists and chemical supply houses. Retail druggists will doubtless be glad to stock ferric phosphate if there is a demand for it or to get it on special order. In case a large number of trees are to be treated it will probably be worth while to have individual needs combined in one order so that discounts for quantity purchases may be available.

Duration of Effect after Treatment. Over a period of years, several hundred trees have been treated on the University campus and the beneficial effect has lasted for from two to four years. It is probable in some cases that the effect may last even longer, but this can be determined only after further observation.

Of 113 trees, from 9 to 32 inches in diameter, which were treated on the University campus in 1938, 20 required treatment again in 1940, and the other 93 have not required treatment to

Figure 4. Showing view of box elder trees in a park at Pine Bluffs, Wyoming. The larger tree in the foreground (right) had been treated with ferric phosphate the current spring. The two smaller trees in the foreground (left and center) had not been treated and were in a chlorotic condition. All the trees treated in this park showed a definite improvement. However, in some cases the dosages used were too small and the tips of some of the branches started to turn yellow late in the summer.

carry them through 1941. Moreover, only 7 of these 93 trees need treatment at the present time (spring of 1942). Several trees on the campus that were left untreated as controls in 1938 have died, and the treated ones beside them are in a vigorous condition. Many more would also be dead had the treatment not been used.

SPECIES OF TREES TREATED WITH IRON INJECTIONS

In the experiments reported here more cottonwoods have been treated than any other species of trees, because this species predominates on the University campus and in other parts of Laramie, where most of this work has been done.

However, box elder, maple, hawthorn, Russian olive, and apple trees have responded to the treatment nearly as well as the cottonwood.

A few chlorotic conifer trees (western yellow pines) have been treated by the injection method to determine (a) if this type of tree responds to iron treatments, and (b) if the conifers are injured by the treatments. No injury was evident, neither was the benefit very pronounced. It is not recommended that chlorotic conifers be treated by the injection method, at least not until after more research has shown effects and best methods. Such trees can be sprayed with a one per cent solution of iron sulfate as described in a foregoing paragraph.

SUMMARY AND CONCLUSIONS

Chlorosis, a common malady of trees and plants in Wyoming and other Rocky Mountain states, has been very destructive to cottonwood and other species of trees in Laramie and in other parts of Wyoming.

Workers elsewhere have shown that the symptoms known as chlorosis, which is the lack of green color in the leaves, may be due to several causes. One of the most common is lack of iron, which may be present in the soil but unavailable because of chemical conditions.

The chlorosis most common in Laramie is apparently due to lack of iron because it can be cured by direct treatment with iron salts.

The experiments reported in this bulletin show that placing ferric phosphate in holes in the tree is the most successful treatment for chlorosis of trees which has been found, and it is recommended. Other ferric salts have also been used successfully, especially ferric citrate.

Ferrous salts have not produced satisfactory results when injected, but a solution of ferrous sulphate (copperas) has corrected the chlorosis of plants, shrubs, and small trees when applied as a spray.

The beneficial effect of the injection of ferric phosphate lasts for a considerable period. Out of 113 trees treated in 1938, only 27 showed the need of another treatment by the end of the season of 1941.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the contributions made by the following workers during the course of this investigation:

The Department of Building and Grounds, University of Wyoming, for the early exploratory work dealing with tree treatments.

Dr. A. F. Vass, Head of the Department of Agronomy and Agricultural Economics, Dr. J. S. Wiant, former Plant Pathologist at this Station, and Prof. T. J. Dunnewald, Research Associate in Soils, who initiated and organized the experimental work and assisted in the various phases reported in this bulletin, and who also devised a chlorosis comparison standard used extensively to classify the campus trees into five degrees of chlorosis.

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